XVI INTERNATIONAL GEOLOGICAL CONGRESS

GUIDEBOOK 21 - - - EXCURSION C–2

CENTRAL OREGON

International Geological Congress
XVI session
United States, 1933

Guidebook 21: Excursion C–2

CENTRAL OREGON

By

RALPH W. CHANEY

UNIVERSITY OF CALIFORNIA

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1932

This guidebook is published under the auspices of the United States Geological Survey, but it is not a part of the Geological Survey's regular series of publications, and the opinions expressed in it and the use of nomenclature do not necessarily conform to Geological Survey usage.

CONTENTS

ILLUSTRATIONS

CENTRAL OREGON

By Ralph W. Chaney

FOREWORD

In the preparation of this summary of the geology and paleontology of central Oregon the writer is particularly indebted to Dr. Edwin T. Hodge, of the University of Oregon, for data regarding the history of the Cascade Mountains and the region to the east. Dr. John P. Buwalda and Dr. Chester Stock, of the California Institute of Technology, have also furnished material of value, and the published work of Dr. Earl L. Packard and Dr. Warren D. Smith, of the University of Oregon, has been drawn on extensively. The studies of Dr. John C. Merriam in the John Day Basin and elsewhere in eastern Oregon, which were begun more than 30 years ago and have continued down to the present time, have served as a basis for the work of the writer in Oregon and for the preparation of this guidebook.

The trip across Oregon from Eugene to Arlington traverses one of the most extensive regions in western America where continental deposits are predominant and where the record of land animals and plants during the Tertiary period is comparatively complete and well known. This region also represents a center of volcanic activity which has extended from the Tertiary down almost into historic times. The Cascade Range, which in its present development originated in later Tertiary time, illustrates the tectonic and volcanic history of Oregon, and its profound influence upon the life both of the Tertiary and the Recent is at once apparent.

From Eugene, the site of the State University of Oregon, in the Willamette (wil-lam'et) Valley, the excursion crosses the Cascade Mountains, the Madras Upland, the Ochoco Mountains, the John Day Basin, and the Columbia River Lava Plateau, as indicated on Plate 1.

GENERAL GEOGRAPHY

Smith (22)[1] has pointed out the twofold character of the climate of Oregon, that in the western part of the State being marine and that on the east side of the Cascade Range of a

[1] Numbers in parentheses refer to bibliography, pp. 13–14.

continental type. As regards both temperature and rainfall, these mountains act as a barrier that limits the mild moist climate to the western third of the State. Along the coast the annual rainfall may exceed 100 inches (2.54 meters), but in most of eastern Oregon it is only 10 to 15 inches (0.25 to 0.38 meter). The difference in climate between the west and the east sides of the Cascade Range is indicated by the great dissimilarity of the forests in a traverse across the State. In the coastal region and from the Willamette Valley up to the crest of the mountains a dense growth of Douglas fir (*Pseudotsuga taxifolia*) and associated conifers will be seen; east of the mountains the yellow pine (*Pinus ponderosa*) extends for a considerable distance out on the Madras Plain, but elsewhere true forests disappear except on the summits of the Ochoco Mountains and other inland ranges; the uplands are occupied by scattered junipers (*Juniperus*) and sage (*Artemisia*), and along the streams there are cottonwoods (*Populus*) and willows (*Salix*). Sheep and cattle raising is the principal occupation of the rather sparse population of eastern Oregon, but excellent highways and the extension of railroads into this part of the State are tending to diversify the activities of its inhabitants. In western Oregon ranching of various types, fruit raising, and lumbering are active industries, and lumbering is also important along the east crest of the Cascades.

GEOLOGY

General features.—The rocks of the Coast Range are largely marine sediments of Tertiary age, with basaltic and other intrusions and with intercalated flows and pyroclastic rocks. The Coast Range represents an anticlinorium, with the steepest folds on the west side and with the Willamette Valley cut into the soft Oligocene tuffs on its eastern slopes. These tuffs dip eastward under the Cascade Range and according to Hodge (14) are a part of a block or series of blocks, including much of northwestern Oregon, which were elevated during Pliocene time along their western edge, with perhaps a fault along the coast. Early Tertiary marine invertebrate faunas have been studied in this area west of the Cascade Range, and near Goshen, a few miles south of Eugene, a lower Tertiary flora contains species whose nearest living equivalents are now found in the low latitudes of both hemispheres.

The Cascade Range in most of Oregon is made up largely of the Columbia River lava, of Miocene age. This volcanic series, which reaches a maximum thickness of about 5,000 feet (1,524 meters), rests upon the Oligocene tuffs and sediments and is inclined eastward across the range; farther east it is faulted down

and extends for the most part in horizontal structure over the State and into Idaho. Hodge (14) has furnished the following section for the Cascades:

Recent: Lava flows from acidic to basic; pyroclastics and stream deposits.
Pleistocene: Andesites of Cascade Range, including basaltic and andesitic flows and interbedded ashes and tuffs. Madras formation,[2] torrential stream deposits, lake beds, and lava flows.
Pliocene: Erosion and deformation.
Miocene: Columbia River lava, basaltic flows.
Oligocene: Cascadia formation, a thick series of agglomerates and tuffs.
Eocene: Highly deformed rhyolitic material, similar to Clarno formation of eastern Oregon, has been found in some of the deep streams cut in the west side of the Cascade Range, notably at Cascadia, on the Santiam River.

East of the Cascade Range, as well as in the range itself, the Columbia River lavas are the most conspicuous and extensive series. Where there has been folding, erosion by the larger streams has exposed the underlying rocks, as in the John Day Basin; only along the lines of the major structural features, such as the Ochoco Mountains, have the Columbia River lavas been extensively removed. The following section is based on Merriam's original section in the John Day Basin (18), slightly modified by the work of Buwalda, Hodge, Packard, and the writer to include the area adjoining this traverse.

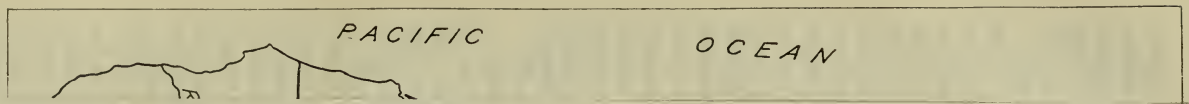
[2] The Madras formation of Hodge includes the upper Miocene Dalles and Hood River formations of Buwalda and Moore and the Pleistocene Deschutes formation of Russell and Stearns. See Hodge, E. T., Framework of Cascade Ranges in Oregon: Pan Am. Geologist, vol. 49, p. 350, June, 1928; Russell, I. C., Geology and water resources of central Oregon: U. S. Geol. Survey Bull. 252, p. 90, 1905; Stearns, H. T., Geology and water resources of the middle Deschutes River Basin, Oregon: U. S. Geol. Survey Water-Supply Paper 637, p. 133, 1931; Buwalda, J. P., and Moore, B. N., The Dalles and Hood River formations and the Columbia River gorge: Carnegie Inst. Washington Pub. 404, pp. 13–26, 1930, and Science, new ser., vol. 66, p. 236, Sept. 9, 1927.

Geologic section for central Oregon

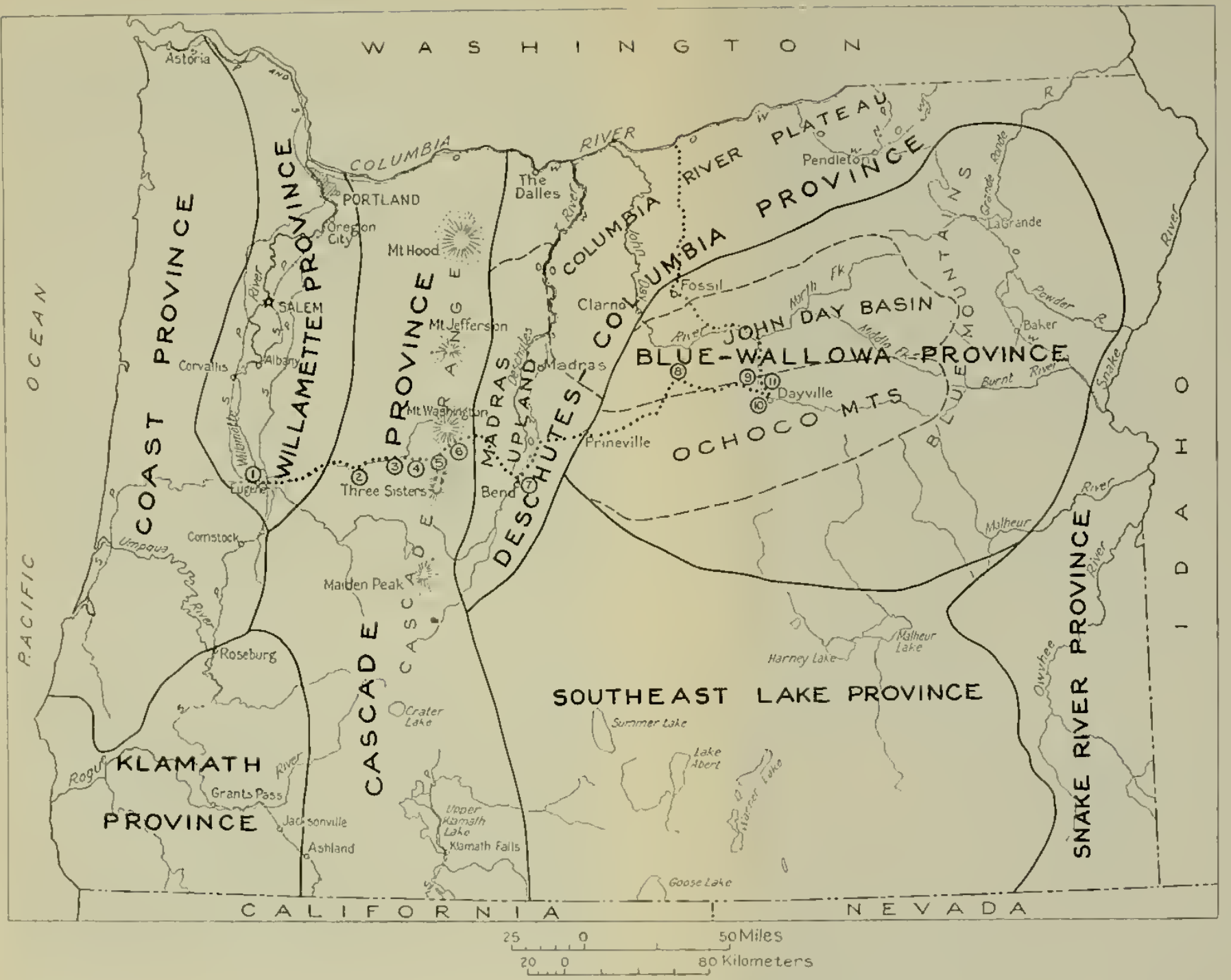
	Age	Formation	Lithology
Cenozoic.	Recent.	Alluvium and terrace deposits.	Sand and gravel.
	Pleistocene.	Glacial deposits.	
			Andesitic and rhyolitic flows, dacites, and tuffs of Cascade Range.
		Madras formation.	Sand, gravel, and lava flows.
	Lower or middle Pliocene.	Rattlesnake formation.	Tuff, gravel, and rhyolitic flows.
	Middle Miocene.	Mascall formation.	Tuff, ash, and possibly gravel.
	Lower Miocene.	Columbia River lava.	Olivine basalt, tuff, and gravel.
	Upper Oligocene.	John Day formation.	Tuff, ash, and rhyolitic tuff and flows.
	Upper or middle Eocene.	Clarno formation.	Shale, tuff, and rhyolitic and andesitic flows.
Mesozoic.	Upper Cretaceous.	Chico formation.	Sandstone, conglomerate, and shale.
	Lower Cretaceous.	Horsetown (?) formation.	Dark fine-grained shale and sandstone.
	Middle and Lower Jurassic.	Silvies River beds; unnamed beds in Ochoco Mountains and on lower Silvies River.	Red impure limestone. Batholithic intrusions; granodiorite.
	Upper Triassic.	Martin Bridge formation.	Calcareous shale, limestone, agglomerate, basalt, andesite, and tuff.

Paleozoic.—There are thick Carboniferous and Permian rocks in the Wallowa Mountains and Elkhorn Ridge.

Triassic and Jurassic.—Invasions of the sea into eastern Oregon during Triassic and Jurassic time resulted in the shoreline deposition of sediments, which have been subsequently folded and eroded. The Wallowa Mountains, in the northeastern part of the State, were uplifted late in the Jurassic



CENTRA



MAP OF CENTRAL OREGON SHOWING GEOMORPHIC SUBDIVISIONS

From data supplied by E. T. Hodge.

period, when there were also extensive intrusions of granular rocks; the principal metallic deposits of northeastern Oregon are related to these intrusives. The present topographic relief of the Wallowa Mountains is due to uplift in late Pliocene or early Pleistocene time.

Cretaceous.—The Cretaceous seas came in from the west, possibly during late Horsetown time, and reached their maximum extension in the Chico epoch. They deposited a thick series of shales, sandstones, and conglomerates, of which the most extensive outcrop is in the Mitchell quadrangle, on the axis of the Mitchell anticline. They are well exposed on the highway below Mitchell. A rich ammonite fauna from these beds has been studied by Packard (21), who concludes that it represents a warm-water assemblage of Indo-Pacific affinities. He has recognized four members in the formation. The lowermost member is characterized by dark fine-grained shales and sandstones which contain a fauna provisionally referred by him to the Horsetown. The three other members consist of nonfossiliferous conglomerates and an intermediate shale series. Only the two shale members have yielded fossils at Mitchell, but a Chico fauna comprising marine invertebrates has been found not far away at Antone, in conglomeratic sandstone. On a hill above Mitchell a small flora made up largely of cycads has been referred provisionally to the Upper Cretaceous by the writer.

The withdrawal of the Cretaceous seas incidental to the Laramide revolution brought the marine history of eastern Oregon to an end. It is possible that a minor uplift along the axis of the Cascade Range served as a barrier to the eastward advance of the Tertiary seas, but it can not be considered to have been high enough to form a climatic barrier.

Eocene.—There is no depositional record for the early part of the Eocene epoch, but from the Willamette Valley westward there are widespread deposits of middle and upper Eocene age. These comprise marine sediments of a shallow-water type, containing abundant marine invertebrates, and terrestrial deposits, largely tuffaceous, containing many fossil plants. The Clarno formation to the east of the Cascade Range is largely volcanic, with rhyolitic and andesitic flows and intrusions, also tuffs and agglomerates which are exposed along the John Day River near Clarno's Ferry. Leaf impressions in the finer tuffs and shales at several localities indicate the middle Eocene age of at least that portion of the formation; but there is some reason to believe that the volcanic activity which gave rise to the Clarno formation continued into the Oligocene, because near Fossil an Oligocene flora occurs in beds referred to the Clarno. A flora of middle or early upper Eocene age from Comstock, about 20

109058—32—2

miles (32 kilometers) south of Eugene, has been studied by Dr. Ethel I. Sanborn, of the University of Oregon, who relates it to similar Eocene floras in southern Oregon and northern California and to the Clarno flora of eastern Oregon. This Comstock flora and a flora of upper Eocene or lower Oligocene age from Goshen, 7 miles (11.2 kilometers) southeast of Eugene, both indicate a warm temperature and proximity to the sea. The Goshen flora has its modern equivalents in Mexico and Central America, with a well-defined Asiatic element, and is more like the Eocene floras of the southeastern United States than any other now known in western America. The Clarno flora is characterized by genera whose modern equivalents require a more temperate climate than those of the Goshen but which indicate a warmer, more humid climate than that of the John Day and later epochs.

Oligocene.—As indicated above, there is some reason for believing that the Clarno volcanic activity was more or less continuous in eastern Oregon during Oligocene time, as marine deposits containing an Oligocene invertebrate fauna in the Willamette Valley and in the Coast Range, to the west, are largely tuffaceous.

The John Day formation which rests unconformably upon the Clarno in the John Day Basin and elsewhere in eastern Oregon, has been considered to be Oligocene on the basis of its mammalian faunas (18), but Stock (25) considers these to represent a distinct advance over the faunas of the Oligocene White River of the Great Plains and to be more nearly related to the lower Rosebud fauna of South Dakota, of upper Oligocene or lower Miocene age. Among the common genera represented are *Paracotylops*, *Eporeodon*, *Gomphotherium*, and *Diceratherium*. The extensive fossil plants of the Bridge Creek flora, from the lower John Day formation, closely resemble Miocene floras from various parts of western America. The John Day formation will therefore be considered under the Miocene, with the reservation that it may be in part of upper Oligocene age. Prior to the John Day epoch the Clarno rocks were slightly folded and widely eroded.

Miocene.—With the deposition of the John Day formation at the end of the Oligocene and the beginning of the Miocene, volcanic activity, though continuing, became subordinate to gradational processes. Most of the sediments making up this formation are of volcanic origin, and some of the ashy shales bearing fossil leaves contain pumiceous fragments which have been transported only a short distance. Merriam (18) has divided the series into three parts—a lower division in which reddish shale predominates and breaks down to form characteristic mud-covered domes; a middle division in which gray to gray-green tuffs and shales are conspicuous, commonly exposed as steep pinnacled cliffs, and an upper division characterized by

buff tuffaceous and ashy deposits. In the lower division occurs the extensive Bridge Creek flora in which *Sequoia* and its associates are represented. Few fossil plants occur in the middle and upper divisions, and these are not greatly unlike the Bridge Creek flora. The middle and upper divisions contain a mammalian fauna of more than 100 species, among which members of the *Oreodon* group are most characteristic. Except for the appearance in the upper division of the genus *Promerycochoerus*, there is little basis for distinguishing the faunas of the middle and upper divisions.

The occurrence of fossil *Sequoia*, together with the Tertiary equivalents of most of the modern associates of the redwood, indicates valley habitats, with a climate not unlike that of to-day along the coast of the northern half of California. This climate, characterized by an annual rainfall of more than 40 inches (1.02 meters) and by mild, equable temperatures, appears to have extended north into Alaska and across to Siberia and Manchuria, where similar floras of presumably the same age have been recognized. The mammalian fauna of the middle and upper parts of the John Day formation indicate well-watered open country.

The Eagle Creek formation, which is exposed in the gorge of the Columbia River west of the Cascade Locks, is probably the equivalent of the upper John Day and contains a flora that has some elements in common with both the Bridge Creek and the Mascall floras; in its lack of the *Sequoia* element it indicates less humid conditions than those of the typical lower John Day formation (Bridge Creek) of the John Day Basin.

The dominantly basaltic Columbia River lavas, resting on the eroded surface of the John Day formation, comprise more than 25 flows of olivine basalt, with intercalated tuff and gravel. This formation formerly covered much of the State of Oregon, forming the great interior plateau and possibly most of the Cascade Range; it extends northward into Washington, eastward into Idaho, and southward into California. Temporary conditions suitable for the growth of forests may be noted in scattered intercalated sediments, of which those exposed along the Columbia River Highway north of The Dalles and containing the remains of large trees show the best development.

After local erosion of the Columbia River lavas, these eruptions gave way to showers of light-colored ash, some of which accumulated in lakes and river valleys and with some sand and conglomerate make up the Mascall formation. This formation is especially well developed near the Mascall ranch, below Dayville (station 10, pl. 1). The vertebrate fauna includes among its representative mammals *Merychippus isonesus*, *Niolabis transmontanus*, *Parahippus*, *Archeohippus*, *Dromomeryx*, *Tephrocyon*,

Amphicyon, and *Leptarctus*. A progressive trend toward aridity is indicated by the Mascall flora, in which *Sequoia* and its associates are no longer dominant; the oaks and other characteristic species have their modern equivalents in the California Coast Ranges, where the annual rainfall is not more than 30 inches (0.76 meter) and where the temperature is more variable than in the redwood belt, to the north. This trend toward aridity, which has continued down to the present time, may be largely attributed to the climatic barrier formed by the rising of the Cascade Range to the west.

The correlative of the Mascall in eastern Oregon and Idaho is the Payette formation. Faunas most nearly related in stage of evolution are those from the Pawnee Creek of Colorado, the lower Snake Creek beds of Nebraska, the Madison Valley of Montana, and the *Merychippus* zone of the north Coalinga region in California. The essential homogeneity of this faunal stage over so broad an area during middle Miocene time is noteworthy.

Pliocene.—The Rattlesnake formation is made up of rhyolitic flows and plugs, with associated gravel and tuff. It rests upon the Mascall with a well-marked structural unconformity at the type locality at the upper end of Picture Gorge, near Dayville (locality 10), and its uppermost rhyolite flow forms a distinct capping wherever the formation has been noted. The fauna is regarded as lower Pliocene and includes *Neohipparion*, *Pliohippus*, *Teleoceras*, *Indarctos oregonensis*, and *Sphenophalos*. It is closely related to that of the Thousand Creek beds of Nevada and is later than that of the Ricardo deposits of the Mohave Desert, California. The Clarendon fauna of Texas is nearly related. No fossil plants are known from the Pliocene of Oregon, but the floras of that age in California indicate increased aridity, which is consistent with the character of the mammalian fauna. The andesites of the Cascade Range may be in part of Pliocene age, but for the most part they appear to be younger and are described under the Pleistocene.

The great diastrophic events that resulted in the formation of the Cascade Range, the Blue Mountains, and possibly also the Ochoco Mountains had their inception late in the Miocene or early in the Pliocene. The Rattlesnake formation is only to a small extent involved in the folding in the Crooked River and John Day Basins. Folding and faulting appear to have continued through much of the Pliocene and in more easterly parts of Oregon are still going on, and the volcanic activity associated with these movements has continued with minor cessations down to the present time.

In the Cascade Range the Pliocene is represented by large amounts of volcanic rocks, which range in composition from

basalts to dacites and in form from flows to pumice. Rocks of similar age occur in southeastern Oregon and form great thicknesses of flows in the plateaus and block-fault ranges south of the Ochoco Mountains. These rocks are but little deformed and lie upon the Miocene and older formations with noticeable unconformity. Together with the Pleistocene lavas they form the present Cascade Range.

Pleistocene.—To the east of the Cascade Range a series of sand, gravel, tuff, agglomerate, and lavas that Hodge has called the Madras formation [3] occurs interbedded with the more recent lavas, which had their origin in the volcanoes of the Cascade Range. Among the more notable peaks that served as vents for these flows are Mount Hood, Mount Jefferson, Three-fingered Jack, and the Three Sisters. Lavas from these later volcanoes cover the earlier volcanic rocks of the range and extending down the valleys on both sides form great flats such as the Madras Plain. Glaciation occurred during the later part of this volcanic activity, and glacial tills are buried by the flows.

Recent.—Glaciers, which during the Pleistocene were numerous, are now confined to a few of the higher peaks. Recent volcanism is indicated not only by fumaroles and hot springs but also by flows and cinder cones whose freshness indicates an age of only a few hundred years at the most. Traces of this volcanic activity may be found in the John Day Basin, where ash beds covered by a few feet of alluvium may be found in sheltered spots. The Recent alluvial deposits are few and are confined to small river benches. Erosion has been great, and exposures of the Tertiary sediments are extensive.

Summary of structure.—There have been several epochs of folding in this region, which are expressed in the relations of both the pre-Tertiary and Tertiary formations in the John Day Basin and the Blue Mountains. Several periods of diastrophism are recorded in the Tertiary. Early Tertiary deformation produced a series of north-south folds involving the Cretaceous, Clarno, and John Day formations. In the next period the Columbia lavas and the Mascall sediments were deformed into the east-west folds of the Ochoco Mountains. Still later was the faulting in the Blue Mountains and the region south of the Ochoco Mountains. The structure of the Cascade Range is complex, but the higher part consists of a chain of volcanic cones and flows of Pliocene and Pleistocene age which have built up the present range on the earlier faulted folds. The structural features east of the Cascade Range are gentle, and the general impression

[3] This formation is in this region the equivalent of the Deschutes formation of Russell and Stearns.

given by the greater part of eastern Oregon is that it is carved from nearly horizontal lavas.

ITINERARY

The excursion starts at Eugene, Oregon.

1.[4] At Skinners Butte is exposed a sheet of Columbia River lava overlying the Oligocene tuffs and marine sediments and dipping eastward toward the Cascade Range. From the top there is a general view of the Coast Range, the Willamette Valley, and the Cascade Mountains. Honeysuckle and Gillespie Buttes are capped by river gravel and indicate the former high level of the Willamette River.

The route leads eastward over the McKenzie Highway, following to a considerable extent the McKenzie River. Here may be seen the river terraces and the eastward dip of the basaltic lavas and tuffs.

Between Walterville and Vida the basaltic lavas that occur along the western margin of the Cascade Range grade through a series of agglomerates and tuffs into the normal andesites characteristic of the main mass of the range between Vida and Belknap Springs. This part of the range includes andesites (variously characterized by labradorite, andesine, and oligoclase), rhyolites, tuffs, and agglomerates.

2. At Indian Creek and at Nimrod are small masses of diorite and granodiorite which intrude the andesites of the main mass of the range.

Four miles (6.4 kilometers) north of the Blue River is the Blue River mining district, which produced $170,000 in gold and silver from the oxidized portions of veins of quartz and brecciated country rock containing sphalerite, galena, chalcopyrite, and pyrite. This association is characteristic of several such mineralized areas along the central axis of the range.

3. At McKenzie Bridge is the end of a tongue of flows of gray olivine basalt which projects westward from the mass of the younger Cascade Range to the east, and which lies between the McKenzie River and Horse Creek, to the south. These lavas are strikingly unconformable with the high range of andesites to the west. Here also is the broad valley flat of glacial outwash. The uneven morainal surface may be noted 4 miles (6.4 kilometers) east of McKenzie Bridge.

4. At the road forks to Belknap Springs (hot springs issuing from agglomerate of the older series) the glaciated valley of Lost Creek is entered. One mile (1.6 kilometers) up the valley

[4] Numbers refer to points so indicated on Plate 1.

is the terminus of a postglacial lava flow which occupies the bottom of the valley.

5. At Deadhorse grade, at the head of the Lost Creek Valley, can be seen the lava flows that tumbled over the steep valley wall. Also from this point is visible to the west the tongue of younger lavas projecting down the old McKenzie Valley and the steep east front of the older Cascade Range.

6. The crater and lavas of the Recent Belknap lava flow (pl. 2, *A*) lie near the highway.

McKenzie Pass, at the summit of the Cascade Range, gives a view of the Three Sisters and other peaks. (See pl. 2, *B*.) From this point the character of the vegetation changes, first to pines and then to junipers and sagebrush. The highway follows the McKenzie lava flow, lying in a valley cut in the andesite surface. This surface is extensively covered by a glaciofluviatile mantle.

On the road from the town of Three Sisters to Bend there is evidence that the andesites of the Cascade Range overlie the Pleistocene Madras formation. On the Madras Plain and in the valley of the Deschutes River the Madras formation is shown to be made up of torrent-laid material of volcanic origin, with associated lava flows.

7. Pilot Butte, a Recent volcanic peak, affords from the top a view of the Cascade Range, to the west, and the Ochoco and Paulina Mountains, to the east and south.

From Bend the highway leads northward to Redmond and eastward over the Madras Plain. On the Madras rim, above the town of Prineville, may be seen the structure of the Columbia River lava on the south side of the Ochoco Mountains.

From Prineville eastward and northward over the Ochoco Highway to Mitchell the road follows the Ochoco Valley and crosses the Ochoco Mountains. A forest of pine, with fir and larch (*Larix*) at the higher levels, obscures most of the geology, but at several points the Clarno formation may be noted. This formation differs from the Columbia River lava in being made up largely of fragmental and explosive volcanic products, with flows and intrusive bodies of relatively small extent. It also contains much rhyolite and andesite rather than basalt. The upfolding of the Ochoco Mountains in an asymmetric anticline with its steepest dips to the north has caused the removal of the Miocene and Oligocene lavas and tuffs and the exposure of the Eocene Clarno, with its bright-colored badlands and pinnacle topography.

On the descent of the north slope the badland topography of the John Day Basin may be seen to the north, with a capping of Columbia River lava on the higher buttes and ridges. Just

below the ranger station Cretaceous conglomerates crop out on the left side of the highway, representing part of a strip extending for some 15 miles (24 kilometers), to Mitchell and beyond, with a thickness of several thousand feet. The unconformity between the Clarno and the underlying Chico is striking. The highway reenters the Clarno formation, which extends down nearly to the covered bridge at Bridge Creek, below Mitchell. This formation contains a well-developed flora, in which *Aralia*, *Cinnamomum*, and other typical Eocene genera are represented. The best locality for collecting is a short distance off the road. The contrast between the warm-temperature Clarno flora, with species related to those now living in low latitudes, and the typically temperate-climate Bridge Creek flora, of middle Tertiary age, will be noted at stop 8.

Near the covered bridge the road crosses the Clarno-Chico contact, and from this point into Mitchell the Cretaceous section is well exposed along the axis of a pre-Clarno fold.

For most of the distance east and south toward Dayville, the road runs along the strike of the Clarno formation, with Rattlesnake rhyolite and gravel capping the ridge to the north. In the canyon of Rock Creek (9, pl. 1) the Miocene Mascall formation overlies the Columbia River lava, and the road enters a narrow gorge in the basalt which extends to the John Day River and Picture Gorge. To the east the Mascall formation is extensively exposed in the vicinity of the Mascall ranch (10, pl. 1); and from this point can be seen the southward-dipping Columbia River lava, on which lies the Mascall formation, without angular unconformity, with a capping of nearly horizontal Rattlesnake rhyolite. (See pl. 3, *B*.)

The type locality of these formations, from which most of the vertebrate material studied by Merriam and Stock has been collected, lies between the Mascall ranch and Picture Gorge. Picture Gorge is the narrowed valley of the John Day River where it crosses the Columbia River lava.

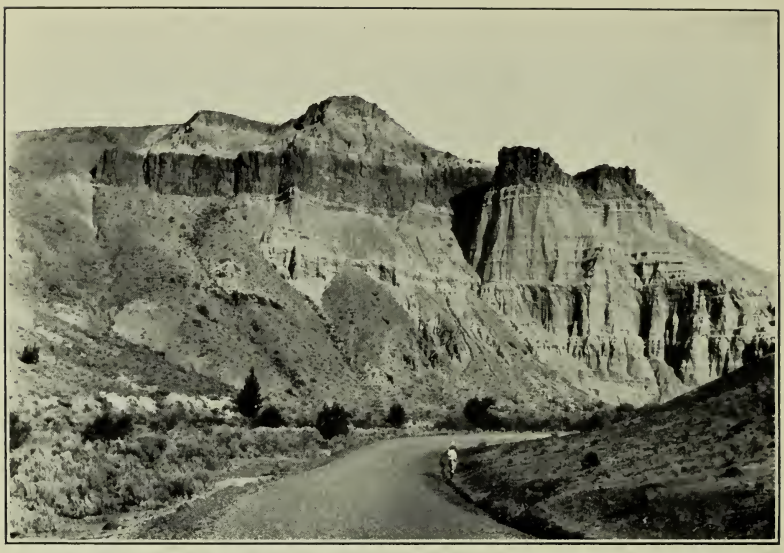
The unconformable contact of the Columbia River lava on the John Day formation may be seen at Sheep Rock (11), where a small mass of basalt caps the summit. A few miles to the north and up the dip conspicuous cliffs of Cretaceous conglomerate are terminated by a fault. The John Day beds (pl. 3, *A*) with overlying basalts of Columbia River lava occupy the valley over a distance of about 25 miles (40 kilometers). The Davis dikes intrude the John Day beds for a distance of several miles along the valley. At several points along the road a layer of Recent ash may be seen covered by alluvium. Beyond Service Creek the route crosses the Grizzly fold, and

A. BELKNAP CRATER

Near the summit of the Cascade Range. From this vent have issued almost within historic times the black olivine basalts exposed on the slopes of the cone.

B. VIEW FROM McKENZIE HIGHWAY NEAR THE SUMMIT

North and Middle Sister Peaks in the background; recent basalt in the foreground.



A. JOHN DAY FORMATION EXPOSED ON JOHN DAY HIGHWAY 15 MILES BELOW DAYVILLE

Showing a rhyolite flow in green and buff tuffs. Photograph by R. W. Chaney.

B. VIEWS NORTHWEST FROM THE MASCALL RANCH

Showing the steeply dipping Columbia River lavas and light-colored Mascall tuffs overlain by the more nearly horizontal Rattlesnake rhyolite. Photograph by R. W. Chaney.

from this point to the town of Fossil, tuffs and lavas of Clarno age are exposed. A narrow outcrop of the John Day is crossed, and basalt flows of the Columbia River lava are followed essentially the entire distance to Arlington, on the Columbia River.

BIBLIOGRAPHY

1. Buwalda, J. P., Report on oil and gas possibilities of eastern Oregon: Mineral Resources of Oregon, vol. 3, No. 2, 47 pp., Oregon Bur. Mines and Geology, 1921.

2. Buwalda, J. P., Paleontological and geological investigations in the John Day region of eastern Oregon: Science, new ser., vol. 66, pp. 135–136, 1927.

3. Buwalda, J. P., A Neocene erosion surface in central Oregon: Carnegie Inst. Washington Pub. 404, pp. 1–10, 1929.

4. Buwalda, J. P., and Moore, B. N., Age of the "Satsop" and The Dalles formations of Oregon and Washington: Science, new ser., vol. 66, p. 236, 1927.

5. Buwalda, J. P., and Moore, B. N., Age of Dalles bed and "Satsop" formation and history of Columbia River gorge (abstract): Pan Am. Geologist, vol. 49, No. 4, p. 313, 1928.

6. Calkins, F. C., A contribution to the petrography of the John Day Basin: California Univ. Dept. Geology Bull., vol. 3, pp. 110–172, 1902.

7. Chaney, R. W., The flora of the Eagle Creek formation: Walker Mus. Contr., vol. 2, pp. 115–181, 1920.

8. Chaney, R. W., Quantitative studies of the Bridge Creek flora: Am. Jour. Sci., 5th ser., vol. 8, pp. 127–144, 1924.

9. Chaney, R. W., The Mascall flora—its distribution and climatic relation: Carnegie Inst. Washington Pub. 349, pp. 23–48, 1925.

10. Chaney, R. W., Geology and paleontology of the Crooked River Basin, with special reference to the Bridge Creek flora: Carnegie Inst. Washington Pub. 346, pp. 45–138, 1927.

11. Chaney, R. W., and Sanborn, E. I., The Goshen flora of west-central Oregon (in preparation).

12. Hodge, E. T., Geology of Mount Jefferson: Mazama, Ann. Ser., vol. 7, No. 2, pp. 25–58, 1925.

13. Hodge, E. T., Mount Multnomah, ancient ancestor of the Three Sisters: Oregon Univ. Pub., vol. 3, No. 2, 160 pp., 1925.

14. Hodge, E. T., Composition and structure of the Cascade Mountains in central Oregon [abstract]: Geol. Soc. America Bull., vol. 38, pp. 162–163, 1927.

15. Hodge, E. T., Columbia River fault: Geol. Soc. America Bull., vol. 42, pp. 923–984, 1931.

16. Hodge, E. T., Exceptional morainelike deposits in Oregon: Geol. Soc. America Bull., vol. 42, pp. 985–1010, 1931.

17. Hodge, E. T., Geologic map of north-central Oregon: Oregon Univ. Pub., vol. 1, No. 5, 1932.

18. Merriam, J. C., A contribution to the geology of the John Day Basin: California Univ. Dept. Geology Bull., vol. 2, pp. 270–314, 1901.

19. Merriam, J. C., Carnivora from the Tertiary formations of the John Day region: California Univ. Dept. Geology Bull., vol. 5, pp. 1–64, 1906.

20. Merriam, J. C., and Sinclair, W. J., Tertiary faunas of the John Day region: California Univ. Dept. Geology Bull., vol. 5, pp. 171–205, 1907.

21. Packard, E. L., A new section of Paleozoic and Mesozoic rocks in central Oregon: Am. Jour. Sci., 5th ser., vol. 15, pp. 221–224, 1928.

22. Smith, W. D., Physical and economic geography of Oregon, ch. 5, Climate: Commonwealth Rev., vol. 7, pp. 11–26, 1925.

23. Smith, W. D., and Packard, E. L., The salient features of the geology of Oregon: Jour. Geology, vol. 27, pp. 79–120, 1919.

24. Stearns, H. T., Geology and water resources of the middle Deschutes River Basin, Oregon: U. S. Geol. Survey Water-Supply Paper 637, pp. 125–220, 1931.

25. Stock, Chester, Oreodonts from the Sespe deposits of South Mountain, Ventura County, California: Carnegie Inst. Washington Pub. 404, pp. 27–42, 1930.